III. THE SACRAMENTO RIVER

The Sacramento River is the largest river in California. It drains a watershed of over 24,000 square miles, most of which lies above the Colusa Subreach. The river receives annual runoff of over twenty-two million acre feet of water and contributes 80% of the fresh water that flows to the Sacramento-San Joaquin Delta. It provides water to farmers in Northern and Central California and cities in Northern, Central and Southern California. Its water sustains the agricultural economy of the Sacramento Valley and it is vitally important to the communities in the Colusa Subreach.

The River also sustains the riparian ecosystem that includes the riparian plant communities, the animals that have adapted to those communities and the animals that utilize the aquatic habitats the river provides. The river is the single greatest source of salmon caught off the California coast. It also sustains public recreation activities, such as hunting, fishing, birding and boating that are enjoyed by thousands of people each year. In short, the Sacramento River is many things to many people and important to all of California.

A. Hydrology and Geomorphology

Stream flow is the primary controlling variable affecting the riverine (related to or formed by the river) environment in the Colusa Subreach. The natural disturbance regime of the river, the intra and inter-annual variability in the flow patterns and all of its associated physical processes are the factors largely responsible for the mosaic of riparian vegetation communities along the river. In the Colusa Subreach, and along the river in general, the preservation and restoration of these physical processes has been identified as the key to successful long-term restoration and maintenance of the riparian ecosystem.

Channel Movement - The processes of channel meander and avulsion are the dominant process that shape the floodplain and associated natural communities along an alluvial river such as the Sacramento River. Meandering involves the river channel migrating laterally through the floodplain, eroding materials on the outside (concave side) of a bend in the channel creating nearly vertical cut banks, while at the same time depositing materials on the inside (convex side) of a bend creating point bars. This combination of erosion on the outside of bends and deposition on the inside results in the familiar meander form when seen on a map or aerial photo. Figure 9 depicts a typical bend on the river. Over time, this continual process of erosion and deposition creates new floodplain area and provides a variety of ecosystem niches for the associated riparian species.

Channel avulsion also creates a dynamic variety of landforms that sustain natural communities along the river. Although channel avulsion is a complex process, it can be described simply as the channel cutting off a bend that has become too tight to maintain. When a meander bend becomes too tight of a turn for the river to maintain, the river will create a straighter path for itself.

Recent analysis has identified at least a third of the riparian communities on the Sacramento River result from this process (Greco, 2000).

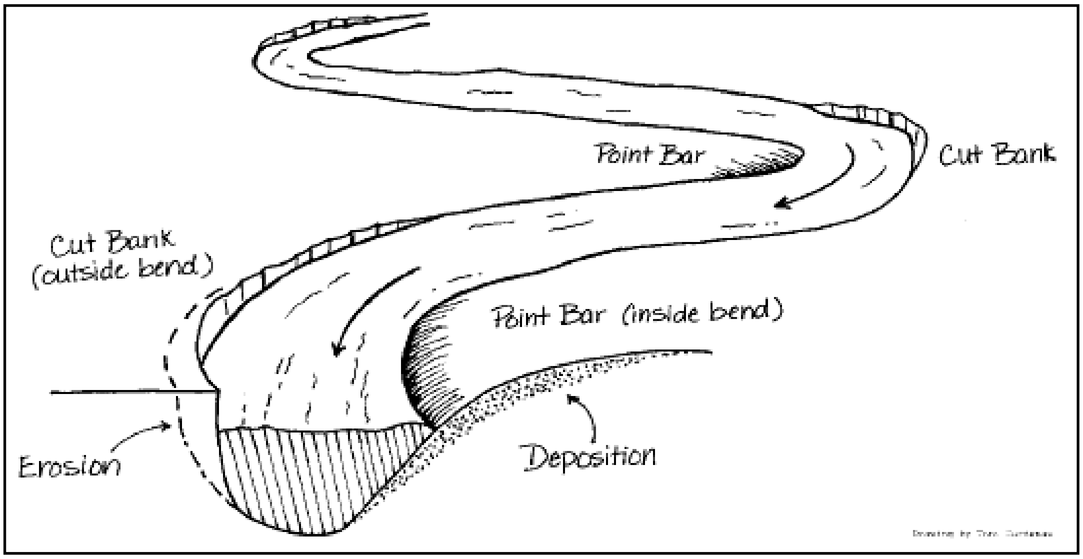

Figure 9. Typical Bend on the Sacramento River

Illustration from the Sacramento River Conservation Area Handbook.

This process leaves evidence on the floodplain in the form of oxbow lakes and sloughs. A slough results from a relatively recent avulsion, where the channel has filled one end in with sediment, generally the upstream end, leaving the bottom or downstream end connected to the river. As more time passes, this bottom end eventually fills in as the river channel moves away from it creating an oxbow lake.

Within the meander belt of the river, the constant movement of the channel can greatly change the configuration of property. Figure 10 depicts the change that has occurred at RM 183 just south of the Ord Bend Bridge. The main river channel moved approximately one mile to the west between 1896 and 1908 as the result of avulsion. An oxbow lake, known as “The Lagoon,” resulted from this sudden shift in the channel location. Since that time, the river has moved progressively east, eroding and redepositing the land in that area. Similar, substantial changes in the river channel location and the resulting reconfiguration of the adjoining land areas have occurred throughout the Colusa Subreach.

This constant changing of the channel can, however, result in impacts to flood control and infrastructure improvements within the Subreach and to the agricultural use of the adjoining land. Movement of the channel can render costly improvements such as pumping plants ineffective if the river moves away from the intake location. A related problem is that channel movement can result in changes to the velocity of the flow, which can impact the effective operation of some fish screen systems. Major changes in channel location can also impact the utility of bridges and boat ramps. Likewise, channel meander can result in the loss of agricultural cropland as the river erodes into orchards or row crop land located on the outside of bends.

A 150 year meander belt has been described and mapped by the Department of Water Resources for the Sacramento River. This meander belt includes the location that the river channel has occupied in the last 100 years (moving both through meander and avulsion), and where it is projected to occupy in the next 50 years. Channel movement can be either incremental or more sudden and this is controlled by the interaction of many complex physical factors. Therefore, the 50-year projections while approximate are still of great value for large-scale planning. Within the Colusa Subreach, the 150 year meander belt is entirely located within the flood control levees and, therefore, within the Planning Area.

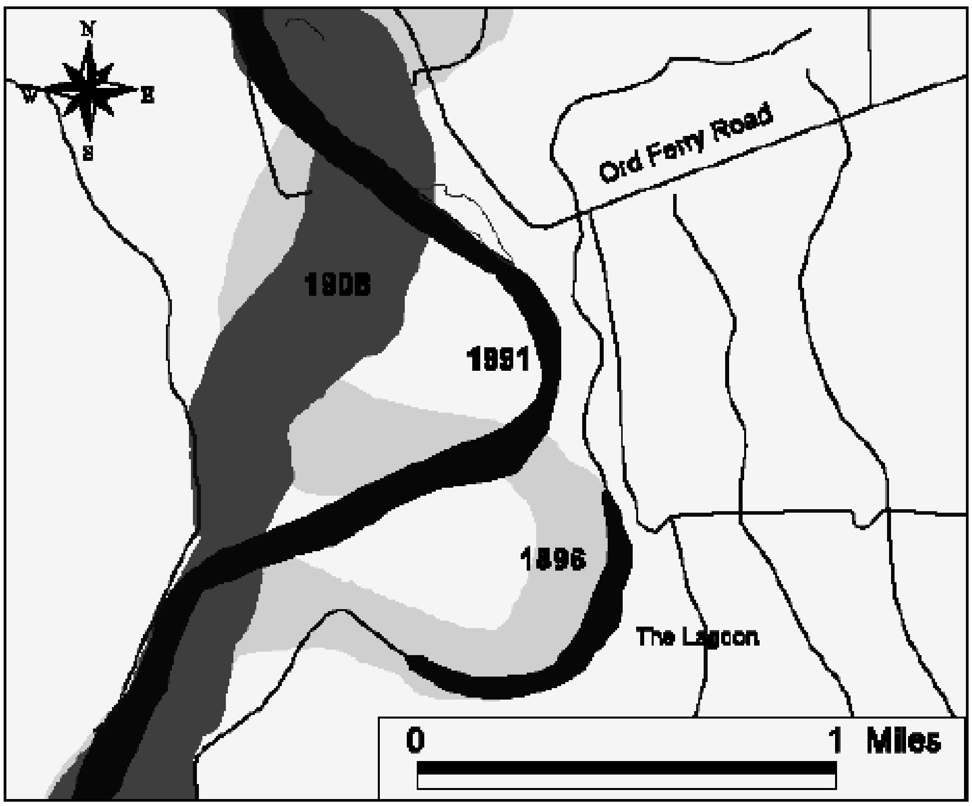

Figure 10. River Channel Movement at RM 183
Illustration from the Sacramento River Conservation Area Handbook.

This combination of gradual meander and sudden avulsion occurs differentially within the Subreach and the river corridor in general. Different soils along the river offer differing resistance to channel movement and, as a result, the river channel is actively moving in some areas and relatively static in other areas. Soils that are highly resistive to channel movement are referred to as geologic control. The presence of these geologic controls results a differential pattern of channel movement. Figure 11 depicts the historical movement of the river channel in the Colusa Subreach. Channel locations from 1896, 1937, 1960, 1976 and 1999 are shown to demonstrate the range of channel movement that

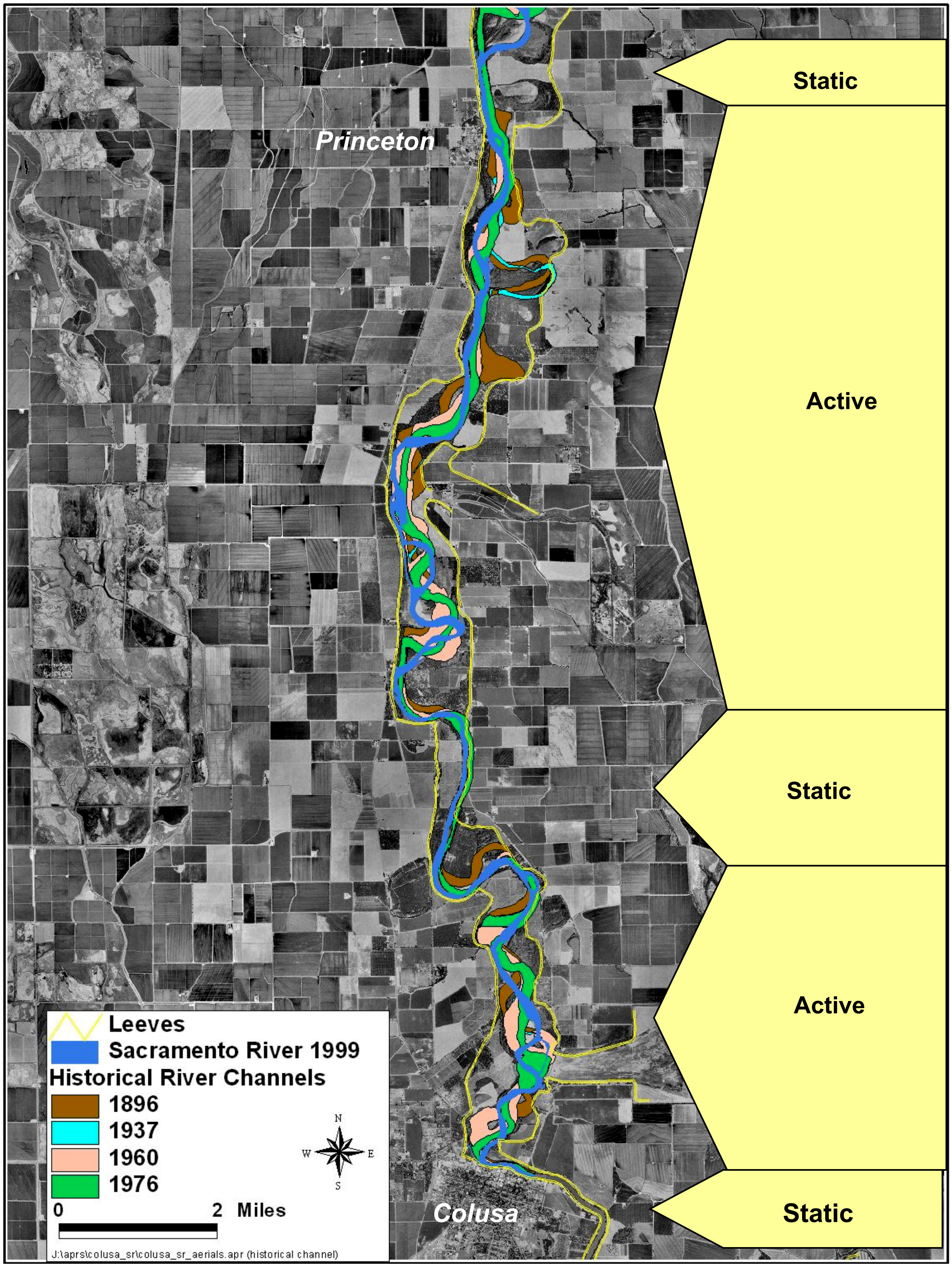

Figure 11. Historic Channel Movement
Source: Sacramento River Geographic Information System

has occurred. Figure 11 also generalizes this channel movement to differentiate where the channel has been historically active and static during the 20th Century.

Bank Protection – As noted previously, the natural movement of the channel can be disruptive to adjacent improvements and land uses. Land areas on one side of the river can be reduced and land areas on the opposite side of the channel can be increased. In response to this natural process, revetment, which is often referred to as bank protection or armoring, has been installed along portions of the middle Sacramento River in an effort to protect substantial investments such as levees, pumping plants, fish screens, buildings, orchards, bridges, other public improvements and adjacent land uses. Within the Colusa Subreach, revetment has been installed along approximately 20% of the river bank in an attempt to limit erosion and the resultant movement of the river channel. Almost all of this revetment has been installed to limit erosion where the river is adjacent to the levee system. Figure 12 depicts the location of revetment within the Subreach as mapped by the California Department of Water Resources. This revetment was primarily installed through state and federal projects.

Bank protection typically involves stripping away existing vegetation and replacing it with riprap, a covering of large rocks or concrete rubble, set at a relatively steep angle to the channel. This alters the rate of channel movement both upstream and downstream. It often, however, relocates and modifies patterns of erosion, but does not completely halt erosion. When the channel migration process is frozen in place at one bend by bank protection, the bend downstream or across the river may erode more rapidly than it would have otherwise (Sacramento River Conservation Area Forum, 2002). Agencies such as the Army Corps of Engineers are attempting to develop analysis that will take offsite impacts into consideration when formulating new bank protection projects and the related mitigation actions that are required. In the past, however, the full offsite and ecological impacts of revetment were generally not considered.

Bank protection has also been shown to have substantial, negative impacts on wildlife, especially fish species. Site-level impacts occur that are directly related to the loss of vegetation and habitat where the bank protection is installed. An example is the loss of the cut banks that are required for bank swallow nesting. Substantial, reach-level impacts also occur. Bank protection halts the formation of new riparian forest and alters the sediment transport regime, a primary driving force in the overall ecological balance of the riverine ecosystem. Another major impact is the loss of large woody debris, a key component of fishery habitat, in the river downstream of the riprap (U.S. Fish and Wildlife Service, 2000). Because of these negative impacts, the placement of new revetment often involves a requirement to appropriately mitigate the negative impact on special-status species such as bank swallows and anadromous fish.

Revetment, which is intended to fix the river in a relatively permanent location, involves a conflict of societal values. The need to protect levees from erosion is a priority given the great importance of the flood control system. Also, given the high cost of infrastructure along the river, there is a

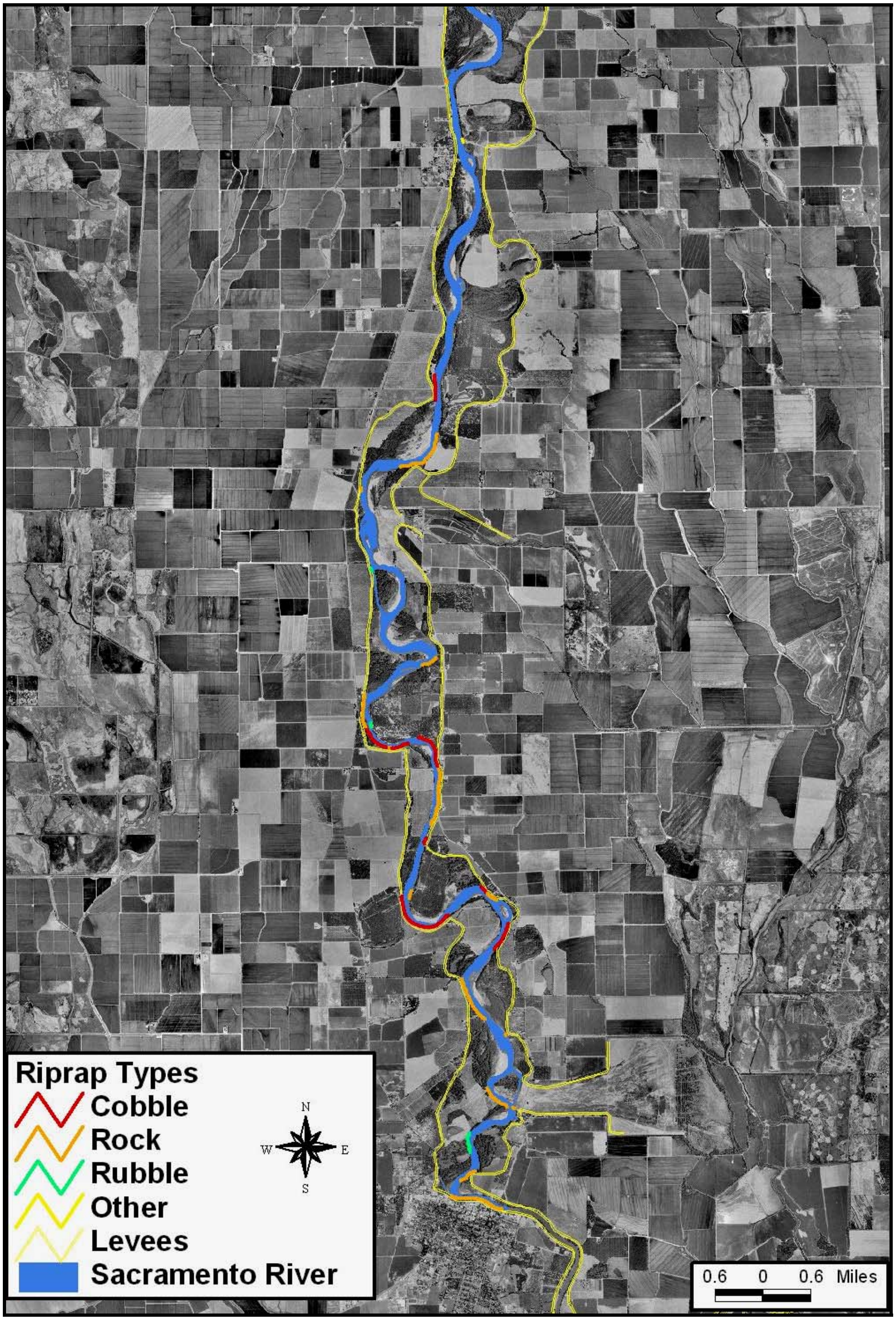

Figure 12. Location of Bank Protection in the Colusa Subreach
Source: California Department of Water Resources

need to maximize the utility and service life of public and private investments. On the other hand, there is a large body of scientific research that documents that the covering of river banks with rock and the stalling of channel meander is very disruptive to the natural systems and directly contributes to the loss of animal species including several Threatened and Endangered Species. In recent years, the general response to this dilemma has been to limit new revetment to locations that are required to protect the flood control system or protect major public infrastructure investment.

Sediment Transport – Sediment transport is the process that supplies the source of materials for land and habitat building. The river works as a conveyor of sediment, transporting materials eroded from upper reaches and depositing them in lower ones. Material transported by the river includes various sizes of rock material, soil, fine vegetative matter and large woody debris. This material is generally deposited on the inside of meander bends, but it is deposited over a larger area of the floodplain in conjunction with flood flows.

The construction of Shasta Dam in the mid 1940's reduced the contribution of sediment from the upper portion of the watershed and modified the natural sediment transport regime. The exact status of the river in terms of sediment transport and balance is a matter of some scientific uncertainty, and additional research and information is needed before management conclusions can be drawn.

Flow Variation and Flooding – The flow regime of the Sacramento River has been substantially changed from the natural situation. Naturally, the river had a pattern of high flows during the winter, rainy season and during the spring when a combination of rain and snowmelt from the higher portions of the watershed generated heavy runoff. Extreme flood flows occurred during these portions of the year. During the summer and early fall, flows diminished to annual, low levels. Upstream regulation, principally by Shasta Dam, has modified the flow regime by greatly reducing the wet season flows and greatly increasing the summer flow levels. High flows during the wet season are stored at Shasta Dam and released during the summer to meet water supply demands for agriculture and municipal uses.

Most of the Planning Area is a low-lying portion of the floodplain that is inundated every year or two on average. For example, most if not all of the Subreach was inundated by the flows that occurred on February 18, 2004. All of the Subreach experiences flooding at least every five years. Figure 13 depicts the frequency of flooding in the Colusa Subreach, as detailed in the Sacramento River GIS. It is important to note, however, that the one and two year inundation designations are based on modeling, which does not incorporate minor elevation differences. Therefore, the diagram should be taken as illustrative of overall flooding patterns, but not as a precise delineation of inundation frequency for specific sites.

Flooding and flow variation are important factors in the creation and maintenance of riparian habitat. While Shasta Dam has substantially regulated the flow regime of the river from its natural conditions, the river still retains some

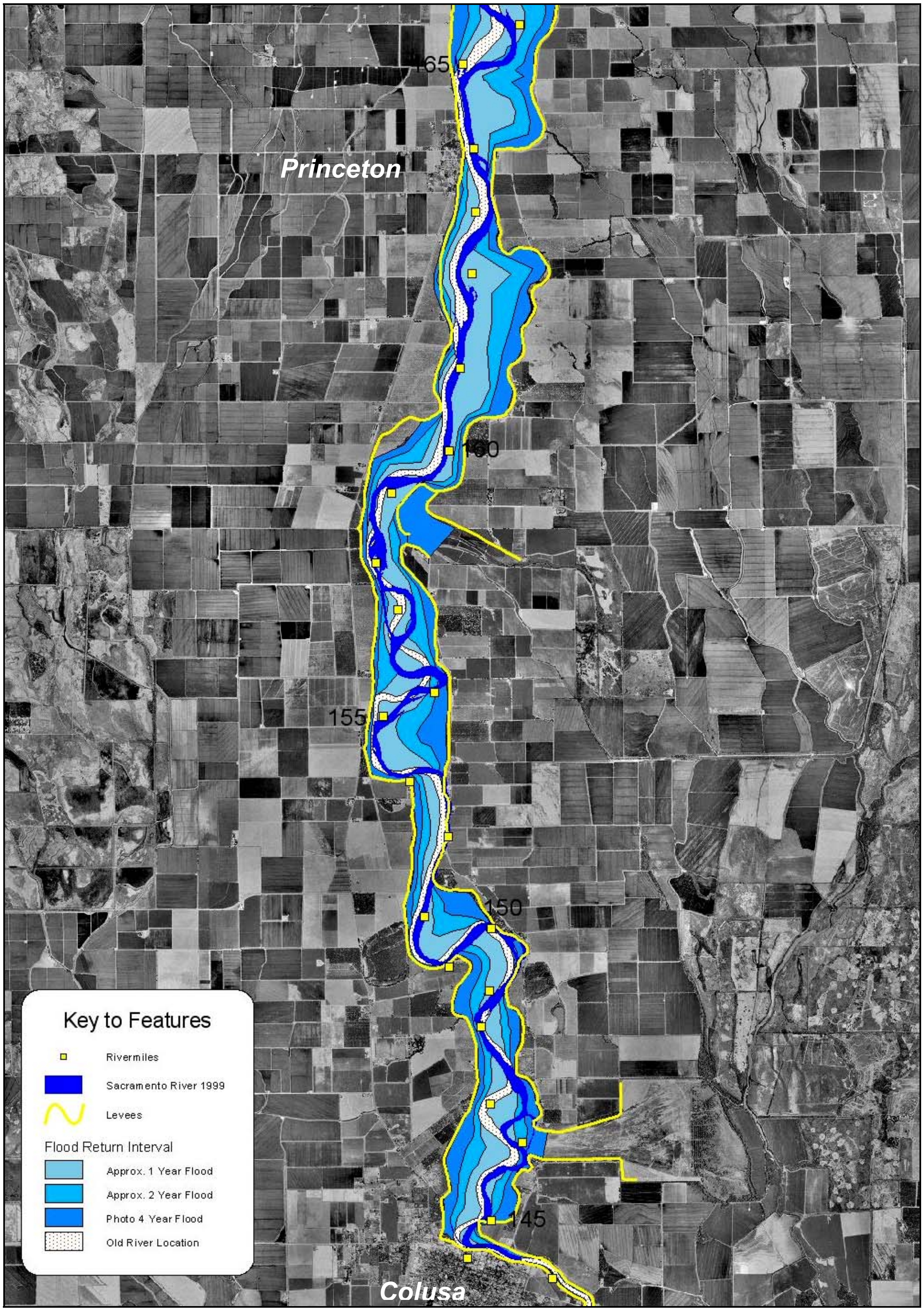

Figure 13. Inundation Frequency in the Colusa Subreach
Source: Sacramento River Geographic Information System

Flooding of the Boggs Bend Area on February 18, 2004

degree of natural flow variability. There are substantial unregulated tributaries below the Dam, which significantly contribute to the present-day flooding and flow regime patterns. Although many aspects of the flow regime have been altered (such as the frequency, magnitude, duration, timing and rate of change) flooding as an important natural change agent has not been eliminated within the levee system. In part, it is this level of natural process and the resulting ecological function that makes the Colusa Subreach important for ecosystem restoration.

Flood flows within the Subreach deposit sediment over the portion of the floodplain that is inundated, building up the level of the land. The sediment also provides mineral and vegetative matter to create and enrich the soil that sustains riparian vegetation. The plants that form the mosaic of riparian habitat have selectively adapted to and depend on this flood regime. Flooding also carries essential nutrients and organic matter to the river and in so doing benefits fish and other aquatic species. Higher flood flows can also impact the floodplain through erosion. This occurs along the outer edge of channel meanders and through the scouring of the area between meanders. The rate and intensity of this erosion is variable and it is affected by the several factors including soil characteristics, vegetative cover and the velocity of the flow.

Concurrent with the evaluation of future water storage and supply options in the Sacramento River watershed, there are studies ongoing that are intended to identify flow regime options that can better support plant and animal life along the river. The intent is to foster flow regimes that support both the river's ecosystem and the demands for irrigation and municipal water supply. A point raised during the CSP public outreach was that some local interests are concerned that flow regime changes could effect flood control water supply considerations.

B. Sacramento River Flood Control Project

All uses in the Colusa Subreach must be considered in the context of the Sacramento River Flood Control Project. The Army Corps of Engineers completed the Project in 1968 and system maintenance is under the jurisdiction of the Reclamation Board with the funding and maintenance provided by a combination of the State Department of Water Resources and local districts. The *Sacramento River Conservation Area Forum Handbook,* Chapter 2*,* contains an overview of the Sacramento River Flood Control Project. Material within this section is adapted from the *Handbook,* from *Battling the Inland Sea*, by Robert Kelly, a historical account of flood control in the Sacramento Valley, and other available sources.

History - The Colusa Subreach flooded annually as flows generated by upstream rain and snowmelt exceed the capacity of the river channel. This pattern resulted in the channel and the adjoining land being built up higher than the lands to the east and west. Flood flows spilled from the river to these lower lands, the Butte Basin on the east and the Colusa Basin on the west, through distributaries channels such as Cheney and Drumheller Sloughs. These basins held water into the summer until a combination of drainage release to the south and evaporation dried the areas. The majority of the flood flows left the river channel north of Colusa and as a result, the river channel downriver from Colusa had a substantially reduced flow capacity.

Initial levees in the Subreach were constructed in the 1870's by local Reclamation Districts. For the next forty years, individual districts in the Subreach and throughout the Sacramento Valley attempted to control annual flooding by constructing ever-higher levees in the hope of limiting flood flows to the river channel and precluding outflow into the basins. These levee systems were not coordinated and often levees on one side of the river resulted in increased flooding across the river or upstream. Ultimately, a series of disastrous floods made it clear that a comprehensive flood control system that included restoration of outflow into the adjoining basins was required. In 1917 the US Congress authorized the Sacramento River Flood Control Project. The project was constructed in increments that included the rebuilding and heightening of some locally-built levees and managed overflow from the main river channel. In the early 1930's, the Moulton and Colusa Weirs were opened to permit major diversion of flood flows from the Subreach into the Butte Basin. By the mid 1940's the Project was able to regularly provide regular flood protection to the lands outside of the levees and the planned overflow areas.

The Existing System - The Sacramento River Flood Control Project was designed to provide flood damage reduction for 800,000 acres of agricultural land as well as the urban areas located in the floodplain. The system was also designed to increase the sediment transport capacity of the river in order to flush out large quantities of debris resulting from gold mining activities in the surrounding mountains. Overall, the Flood Control Project mimics the spatial patterns of natural historic flood flows with a complex system of levees, weirs for diversion of floodwaters, off-stream floodways and channel modifications. The Flood Control Project levees begin in the vicinity of the Ord Ferry Bridge (RM 184) and extend downstream to the mouth of the river.

The Flood Control Project is assisted by the regulation of flood flows that is afforded by Shasta Dam on the Sacramento River and, to a lesser degree, by Black Butte Dam on Stony Creek. Shasta Dam has storage capacity of 4.5 million acre feet, of which 1.3 million acre feet are dedicated to flood control. Shasta controls the runoff from the upper 6,420 square miles of the watershed and it substantially limits flood flow contribution from the upper watershed. The river, however, receives unregulated flows from major tributaries below Shasta Dam that drain the east and west sides of the Sacramento Valley. These flows, as well as occasional high releases from Shasta Dam, result in flows in the Colusa Subreach that still exceed the capacity of the channel on an annual basis.

Within the Colusa Subreach, the Flood Control Project is designed to limit river-related flood damage by restricting design flows to the area inside the levees. Figure 14 depicts the key features of the Flood Control Project in the Colusa Subreach. The channel in the northern portion of the Subreach has design flow of 150,000 cubic feet per second (cfs). The levees north of Colusa are often set back several thousand feet, on one or both sides of the river, such that the total levee-to-levee width of the floodway is over a mile in several sections of the Subreach. This total floodway width, however, varies greatly and in three locations the width is reduced to less than 2000 feet. At its narrowest point, about RM 153, the floodway is only about 1,250 feet wide.

The Project utilizes three natural overflows north of the Subreach (M&T, Three B's and Goose Lake) as well as two major overflow structures in the Subreach (Moulton Weir and Colusa Weir). Together these five diversions are designed to transfer about 70% of the river's flood flow east to the Butte Basin. The Moulton Weir has a design flow of 40,000 cfs and the Colusa Weir has a design flow of 60,000 cfs, equaling a total diversion of 100,000 cfs from the river. This diversion is designed to accommodate the reduction in the floodway width and capacity that occurs from the City of Colusa southward. The levees from Colusa southward are generally adjacent to the river bank and the design flow for the channel is reduced to 65,000 cfs. All flow figures in this section are taken from the *Handbook,* Figure 2-14.

System Maintenance – The flood control system is maintained by multiple entities. These include the U.S. Bureau of Reclamation which operates Shasta Dam and the U.S. Army Corps of Engineers (USACE) which operates Black Butte Dam. The levee system is maintained by a combination of local and state agencies with annual funding coming from both local and state sources. The California Department of Water Resources (CDWR) is responsible for maintenance of the weirs and bypass channels.

Within the Colusa County portion of the Subreach, levee maintenance is performed by CDWR. Funding for maintenance on the west side of the river comes from local assessments that are collected by Colusa County pursuant to a Maintenance Area. Funding for the east side of the river comes from the State General Fund. The portion of the Subreach within Glenn County has levee maintenance performed by Levee District No. 3, an independent local district funded by property tax.

Levee maintenance generally includes vegetation and rodent management on the levees, minor levee repair and limited vegetation and debris removal inside

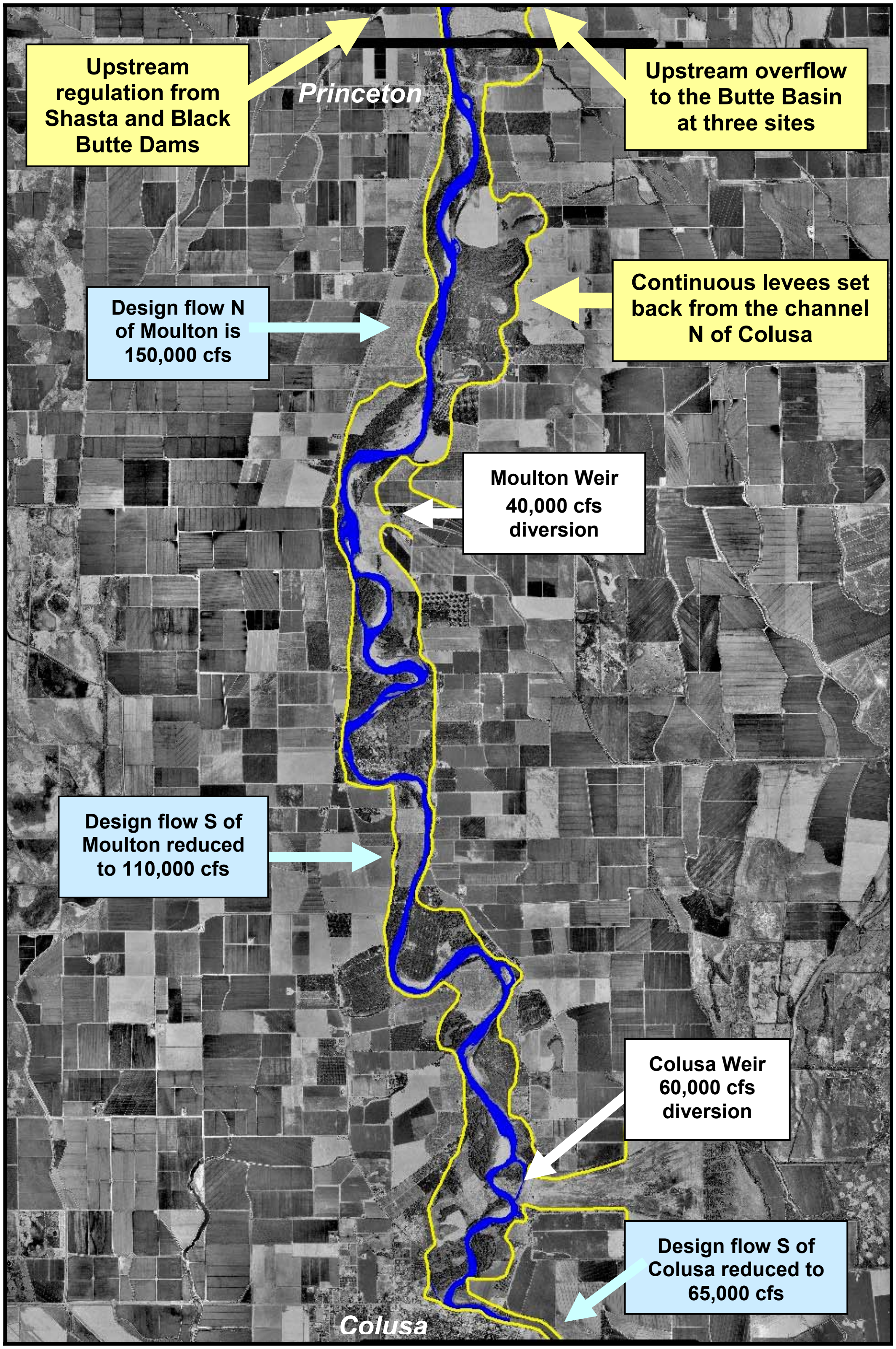

Figure 14. Sacramento River Flood Control Project Features
Source: Design Flow data from the SRCAF Handbook, Figure 2-14

of the levees. Activities do not generally include the channel area. Basic maintenance budgets are not adequate to fund larger levee repair projects and those more expensive projects require other state or federal funding sources that are not always available. Maintenance activities do not include reconstruction or retrofit of levees for increased integrity. In locations where system integrity is at risk, work is usually done by the ACOE and State Reclamation Board under the emergency authority of the PL-84-99 Program.

CDWR activities that relate to weirs and bypass areas include limited annual debris removal, scour hole repair and vegetation management. In weir and bypass areas below the Colusa Subreach, such as the Tisdale Weir, sedimentation is a problem that is not addressed on a regular basis. Overall maintenance resources have been reduced in recent years due to the State's budget deficit. Between 2000 and 2004 the budget for the Flood management division of DWR was reduced by 74% (Leavenworth, 2004). Maintenance funding does not come from a dedicated source and it must compete with other legislative priorities as part of the annual State budget process. Local interests have often been critical of the overall maintenance effort related to the Sacramento River Flood Control Project. A recent report issued by CDWR, *Flood Warnings: Responding to California's Flood Crisis,* concludes that additional local and State funding sources are required to support adequate levels of maintenance.

The US Army Corps of Engineers and the California Department of Water Resources conduct an annual field inspection of the levee system to identify and monitor erosion of the levees. A report is subsequently prepared which serves as a guide to future repair activities. The most recent publicly available report, *2003 Field Reconnaissance Report of Bank Erosion Sites-Sacramento River Flood Control Levees and Tributaries* was prepared by Ayres Associates, the hydraulic analysis subcontractor for Colusa Subreach Planning. Ayres prepared a subsequent report in 2004 that has not been released by the ACOE. The 2003 report noted 101 erosion sites on Sacramento River levees that were being monitored, with 20 of those sites categorized as, "Critical." Six of the monitored erosion sites were within the Colusa Subreach at the following River Mile locations: 149.8L, 154.5R, 163L, 164R, 164.3R, 164.4R. One site at River Mile164R was categorized as "Critical." In the 2004 report, the site at River Mile149.8L was deleted and an additional site at RM 157.7 was added.

Public input received as part of CSP indicates that many local residents are concerned about the current adequacy of the flood control system. This leads to their further concerns that restoration of wildlife habitat within the Colusa Subreach may reduce flood protection for the area outside of the levees. Comments have included a shared perception that the flood control system is not adequately maintained and that the ability of the system to carry the design flows has been compromised. Perceptions that are cited in conjunction with this perspective include:

- Past maintenance activities included dredging and debris removal within the channel that kept the channel more open.
- Buildup of large woody debris has resulted in sediment build-up within the channel.
- There is increased pressure on the levees and inadequate maintenance is provided.

- There is a critical need to clean out weirs and bypasses.
- Environmental review and mitigation requirements have increased maintenance costs and delayed implementation of projects.

Hydraulic analysis that will be conducted as part of CSP will directly address channel capacity to carry design flows with and without restoration projects. It is also anticipated that the Advisory Workgroup will identify research projects that will provide information to help evaluate other questions related to the flood control system.

System Effects – The construction of the flood control system made significant expansion of the local agricultural economy possible by virtually eliminating the annual occurrence of flooding from the Sacramento River for the area outside of the levees. As such, the ongoing maintenance of this system facilities and system capacities are of paramount importance to residents of the entire Sacramento Valley. Local public input received as part of CSP has stressed that protecting the integrity of the Sacramento River Flood Control Project is a critical part of any ecosystem restoration strategy.

The Flood Control Project affects the natural river process in various ways depending on the location. The Project levees through much of the Subreach are setback from the channel, accommodating continued channel meander where bank protection has not been installed. Though upstream regulation has reduced the annual occurrence and intensity of flooding, within the levee system annual flooding still occurs. This flooding helps sustain some limited natural river process, which, in turn, helps to sustain the ecosystem. South of the Colusa Subreach, the flood control levees, and often bank protection, are directly adjacent to the river channel, effectively limiting channel meander and the natural process of habitat formation and maintenance. The Sacramento River Flood Control Project serves a large area and flood damage reduction is an important State and local priority. Therefore, the interrelationship between the flood damage reduction system, the riparian habitat and other uses of the floodway must be considered as part of planning for ecosystem restoration in the Colusa Subreach.

Regulation - The State Reclamation Board is charged with the responsibility of maintaining the integrity of the Sacramento River Flood Control Project. The Reclamation Board reviews proposals for physical change within the "Designated Floodway" to ensure that such projects will not cause new flooding problems. For the Colusa Subreach, the Designated Floodway is the area inside of the levees. This jurisdiction is applicable to most substantive improvements within the Subreach such as levees, bridges, planting to restore riparian habitat, etc. Accordingly, habitat restoration plans that are developed as a part of CSP will be subject to hydraulic modeling and analysis to ensure that they do not diminish the integrity of the Flood Control Project per the standards of the Reclamation Board. Prior to the planting of native vegetation restoration plans will also be subject to review and permit approval by the Reclamation Board per its established jurisdiction.

C. Sacramento River Bank Protection Project

To support the objectives of the Sacramento River Flood Control Project, the Sacramento River Bank Protection Project was authorized by the U.S. congress in 1960 and a second phase was authorized in 1973. The purpose of the Project was to reduce the need for emergency levee repair, periodic dredging, and loss of land area due to channel meander. This was to be accomplished by revetment that typically involved stripping away existing vegetation and replacing it with rock riprap.

In addition to the revetment that was installed as part of the Sacramento River Bank Protection Project portions of river bank have also been modified through state projects and private landowner projects. Concrete rubble has sometimes been dumped over eroding banks and other materials such as cobbles and car bodies were occasionally utilized in the past. Generally, the private projects have occurred without required review or permits from the Reclamation Board and the U.S. Army Corps of Engineers.

Eventually, the ecosystem impacts of bank protection became an issue and all of the authorized bank protection sites were not completed. Recreation and conservation interests objected strongly to the losses of fish, wildlife and aesthetic resources that occurred from revetment. State and federal agencies also determined that bank protection constituted a further threat to Threatened and Endangered Species, such as bank swallows and fish. Additionally, there were concerns that bank protection could act to transfer erosive impacts to different properties.

Direct ecosystem impacts occur to relatively small-scale areas when native vegetation is removed from the project levee or riverbank and replaced with rock. More importantly, long-term and much larger scale impacts to the overall ecosystem result from halting the process of river channel meander. As described previously in this Chapter, this meander is one of the fundamental processes that creates and maintains the diverse mosaic of riparian communities.

Nonetheless, it is recognized that bank protection has an important purpose in protecting levees from erosion in order to maintain the flood control system and the benefits that it provides. It is also recognized that major public investments, like bridges and pumping plants, may require protection from erosion. The *Handbook* incorporates the concept of "limited meander." This concept acknowledges that some revetment is required to maintain the flood control levees and key infrastructure features. Review of each individual revetment project is dictated by current regulations in order to evaluate the effect on the environment and on neighboring properties. There remains, however, strong interest in developing a more comprehensive program, which will not only protect the levee system, but that will also preserve riparian environmental attributes (Sacramento River Conservation Area Forum, 2003). The conflicting objectives, of channel stabilization through bank protection and the protection of wildlife habitat and special-status species are recognized, but not yet resolved.